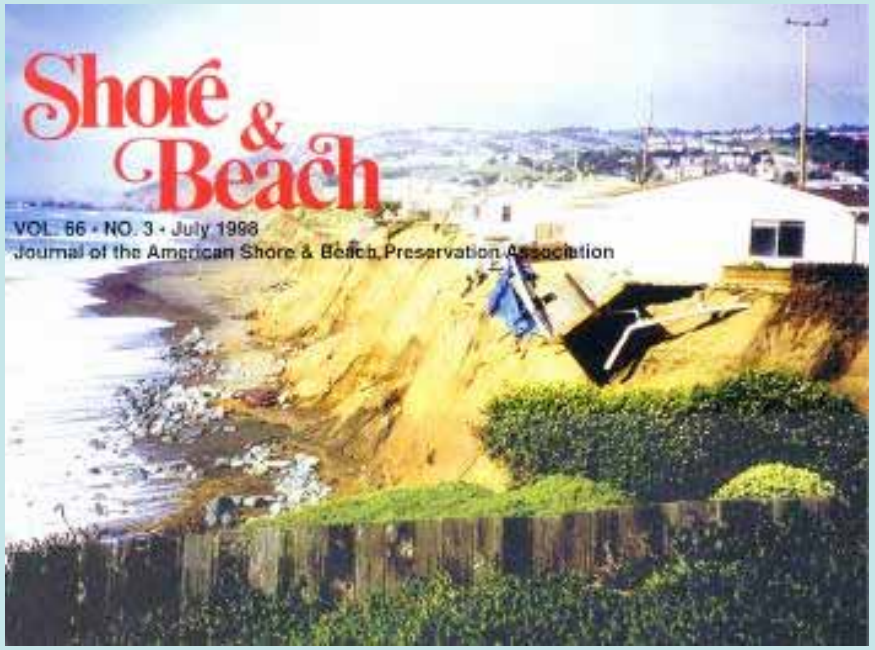
An Initial Assessment of the Effects of Sea Level Rise on Coastal Hazards in California

Photo by D. Revell – 2/23/08



6th Annual California Climate Change Conference

9/9/9

Dr. David Revell, et al…

Robert Battalio, P.E., Justin Vandever, Brian Spear,

Dr. Cheryl Hapke, Dr. Peter Ruggiero, Dr. Gary Griggs…

Outline

- **Background**
- Evaluate future erosion and flooding hazards using the best available data sets, for multiple planning horizons… and hurry!
- **Project Objectives**
- Map Flood and Erosion Hazards
- Identify vulnerable infrastructure
- **Overview of Methods**
- **Results**
- **Adaptation Case Studies**
- **Policy Recommendations**

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CALIFORNIA OCEAN PROTECTION COUNCIL

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General Approach - Vulnerability

- Adopt CA climate scenarios from CEC projects
  - (Cayan et al… A2 - 1.4m)
- Expand 1990 Pacific Institute Study of SF Bay
- Map future flood & erosion hazards for CA coast
- Quantify populations and infrastructure at risk
- Offer policy guidance and recommendations

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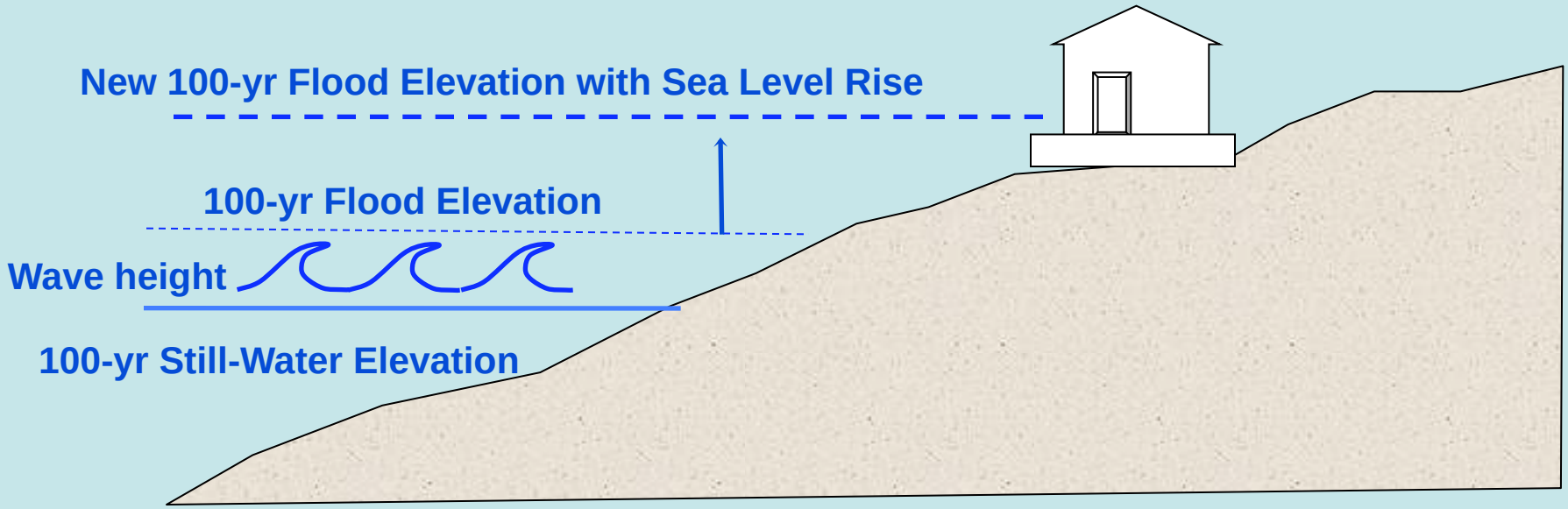
Risk - Mapping Flood Hazards



- Review all existing FEMA Flood Insurance Studies
- Extract Coastal Base Flood Elevations into GIS
- Add Sea level rise scenarios to BFE elevations
- Map inundation using terrain datasets
- Method 2 – Calculated 100yr TWL at ~4100 sites

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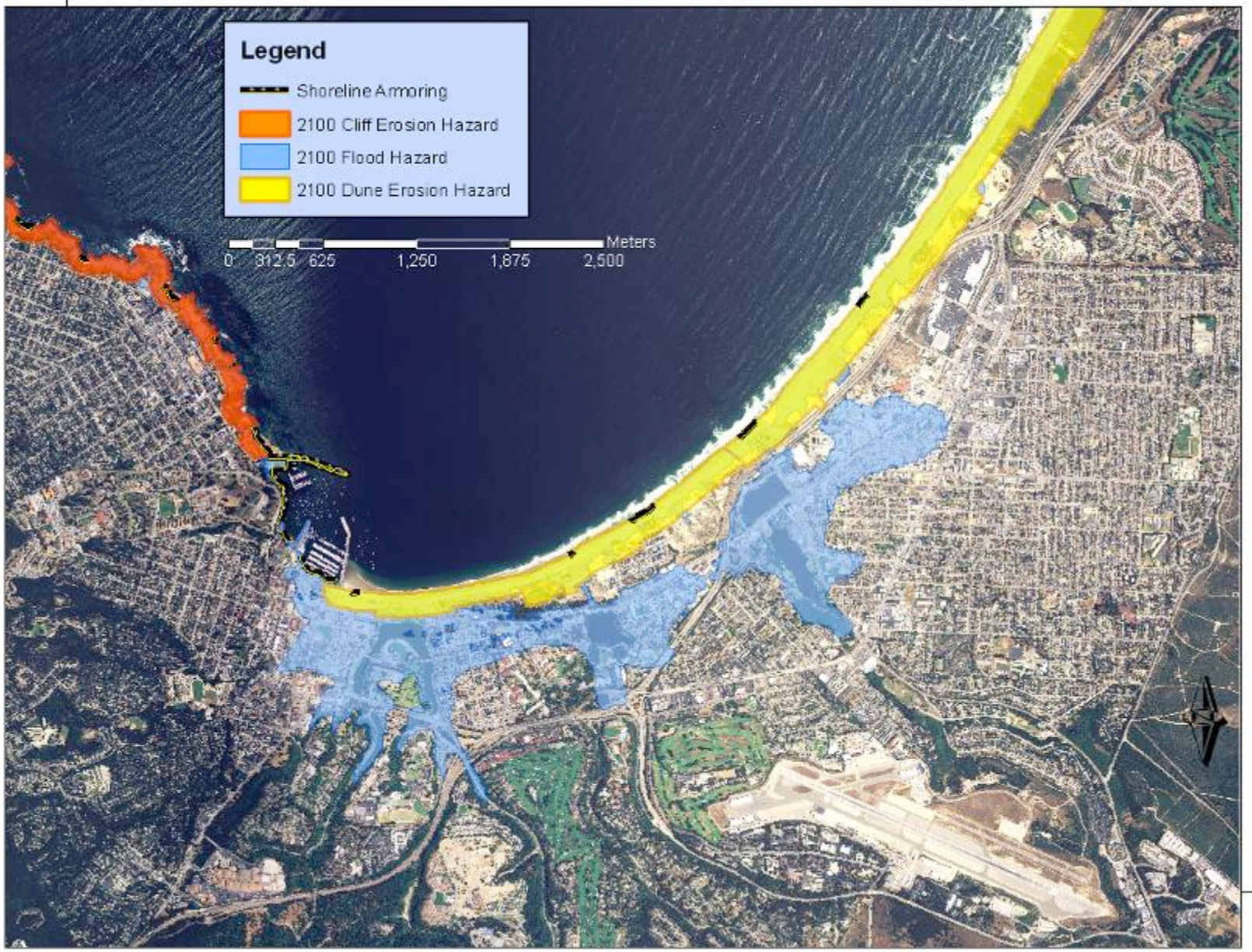
Inundation Maps



Risk - Mapping Erosion Hazards

Total Water Levels

- Sea Level Rise
- Tides
- Wave Run-up
- Storm Surge
- El Ninos

Exceeds

Elevation of the Toe of Cliff or Dune

Causes

Erosion Response

- Backshore Type
- Geology
- Failure Mechanism
- Shoreline Change

Climate Change

- Sea Level Rise
- Wave Climate

Shore Change

- Accelerated Erosion
- Inland Migration of Shore
- Loss of Upland

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Study Area - Erosion

Oregon Border to Santa Barbara Harbor

Gaps –

- Lost Coast
- Big Sur
- Devils Slide

So. Cal – Other studies

USGS – Coastal Hazards

San Diego Foundation

CEC – Scripps Adams and Inman

Why didn't you do SoCal?!

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Backshore Types

- Dune/Inlet
- Cliff/ Bluff
- Landslide
- Armored

California Coastal Records Project

GIS data:

Shoreline Inventory, Geology, Armoring, Landslides, LIDAR, Bathymetry, Sandy Shoreline change rates, Cliff Erosion rates.

Non GIS references:

Griggs et al Living with the Changing California Coast 2005
California Coastal Records Project

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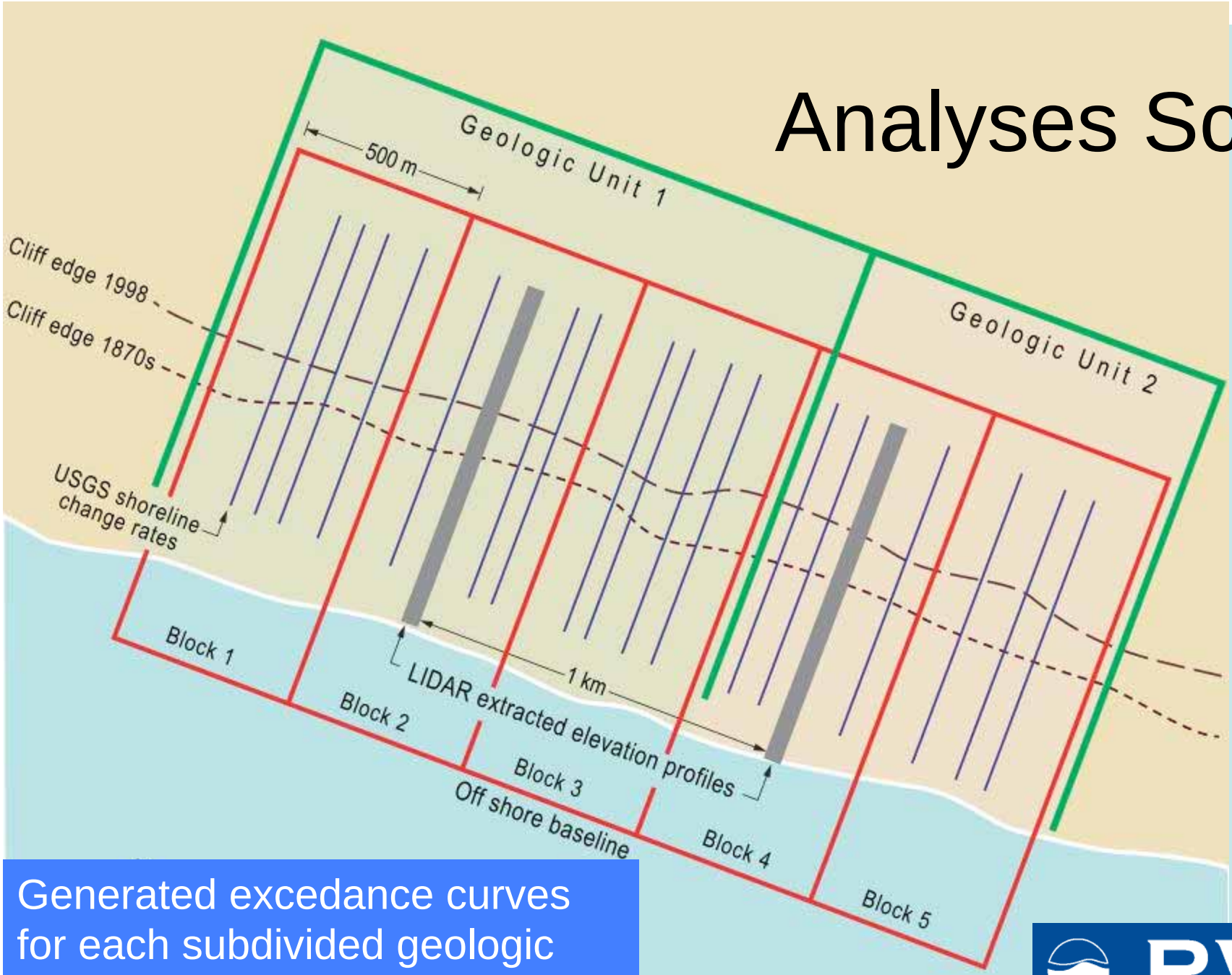
Analyses Scale



Generated excedance curves for each subdivided geologic unit (500m) using individual slopes and toe elevations

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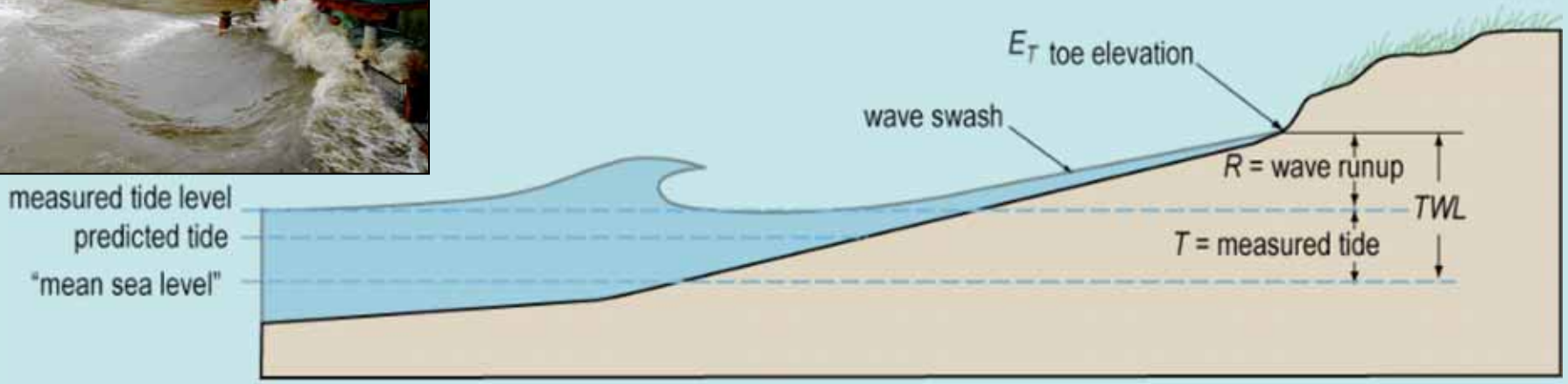
Total Water Levels



Total Water Level, TWL = "measured" Tides, **(T)** + Wave Runup, **(R)**

T = Sea level rise scenarios (Cayan et al), 100 years at 3 hour tides coupled waves and storm effects (ENSO, surge) for 2 scenarios
2 locations – San Francisco, Crescent City

R = Wave run-up - Deepwater waves (Cayan et al) for three sites –
Pt. Conception, San Francisco, Crescent City

- CDIP models to transform waves at 140 nearshore locations at 10m
- Calculated wave run-up (Stockdon et al 2006).

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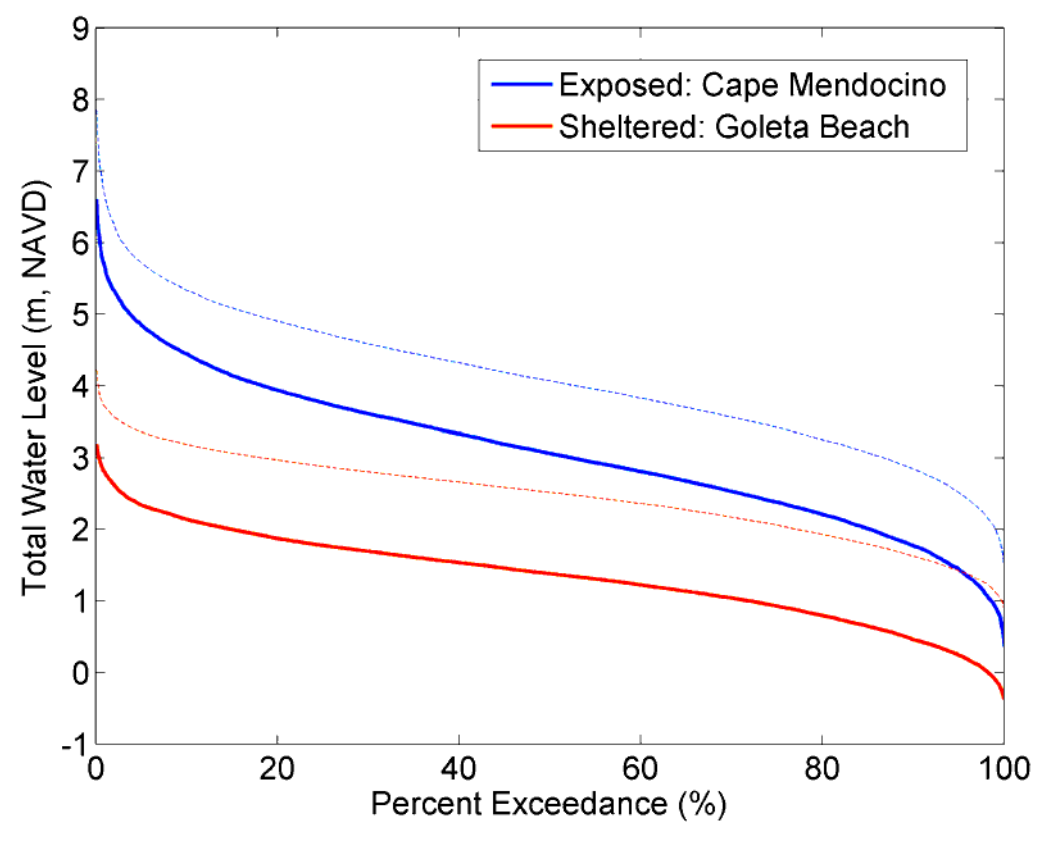
Total Water Levels



- Combined SLR and Wave Run-up
- Generate excedance curves for each subdivided geologic block using individual slopes and toe elevations

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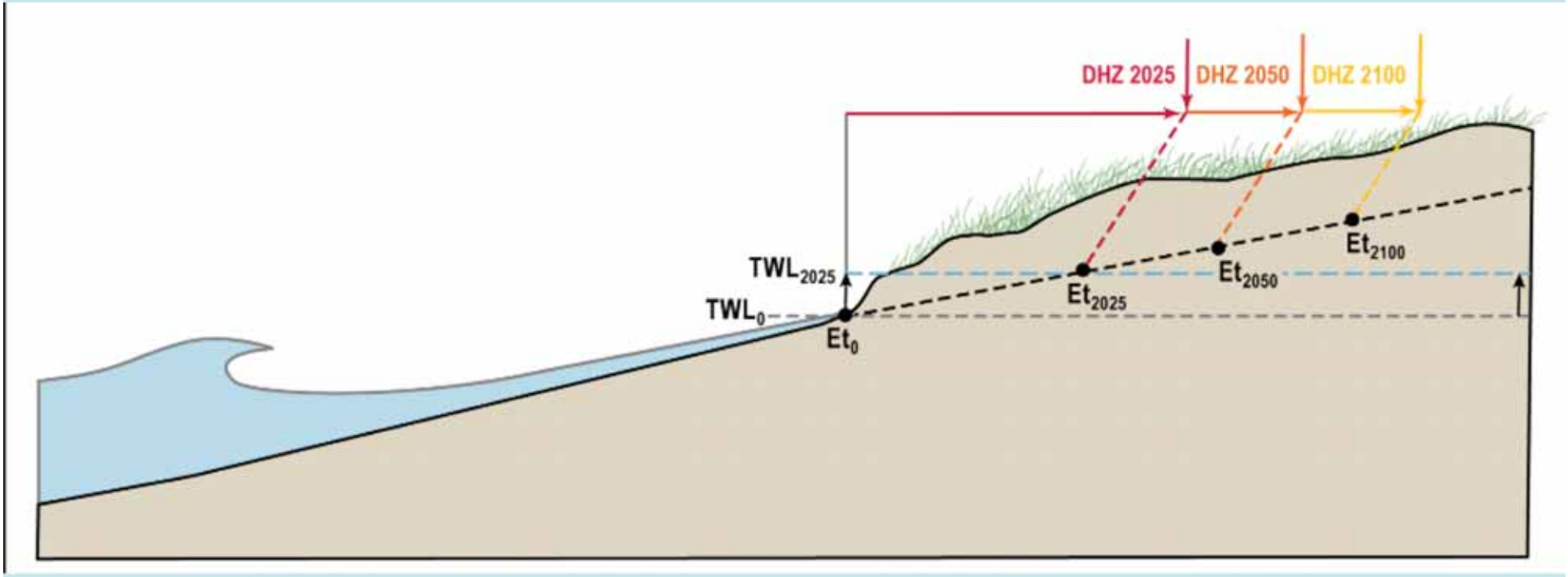
Dune Erosion Model



- 3 components –
  - Changes in TWL from SLR combined with shoreface slope
  - Historic shoreline trends (USGS)
  - Impact of a “100 year storm event”

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Dune Hazard Zones

Air Photo from 2005

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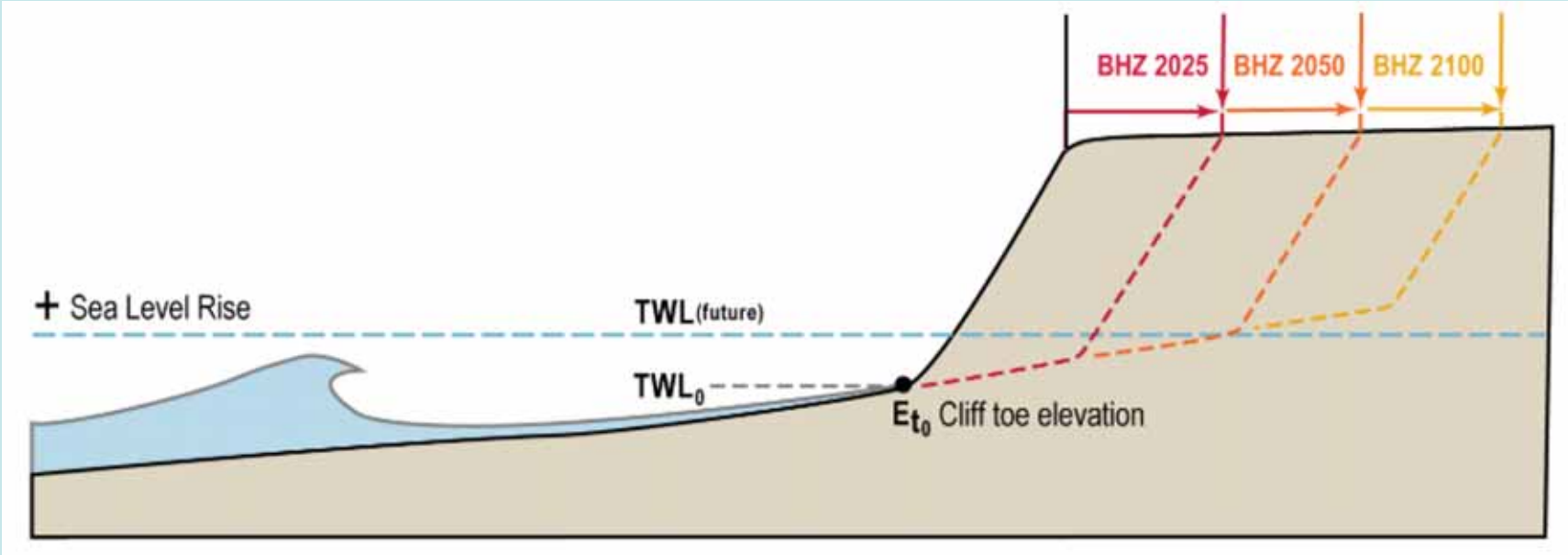
Cliff Erosion Model



- Acceleration of historic erosion rates (Rh)
- Prorated based on % increase in TWL exceeding the elevation of the toe of the beach/cliff junction
- Include geologic unit standard deviation x planning horizon to account for alongshore variability

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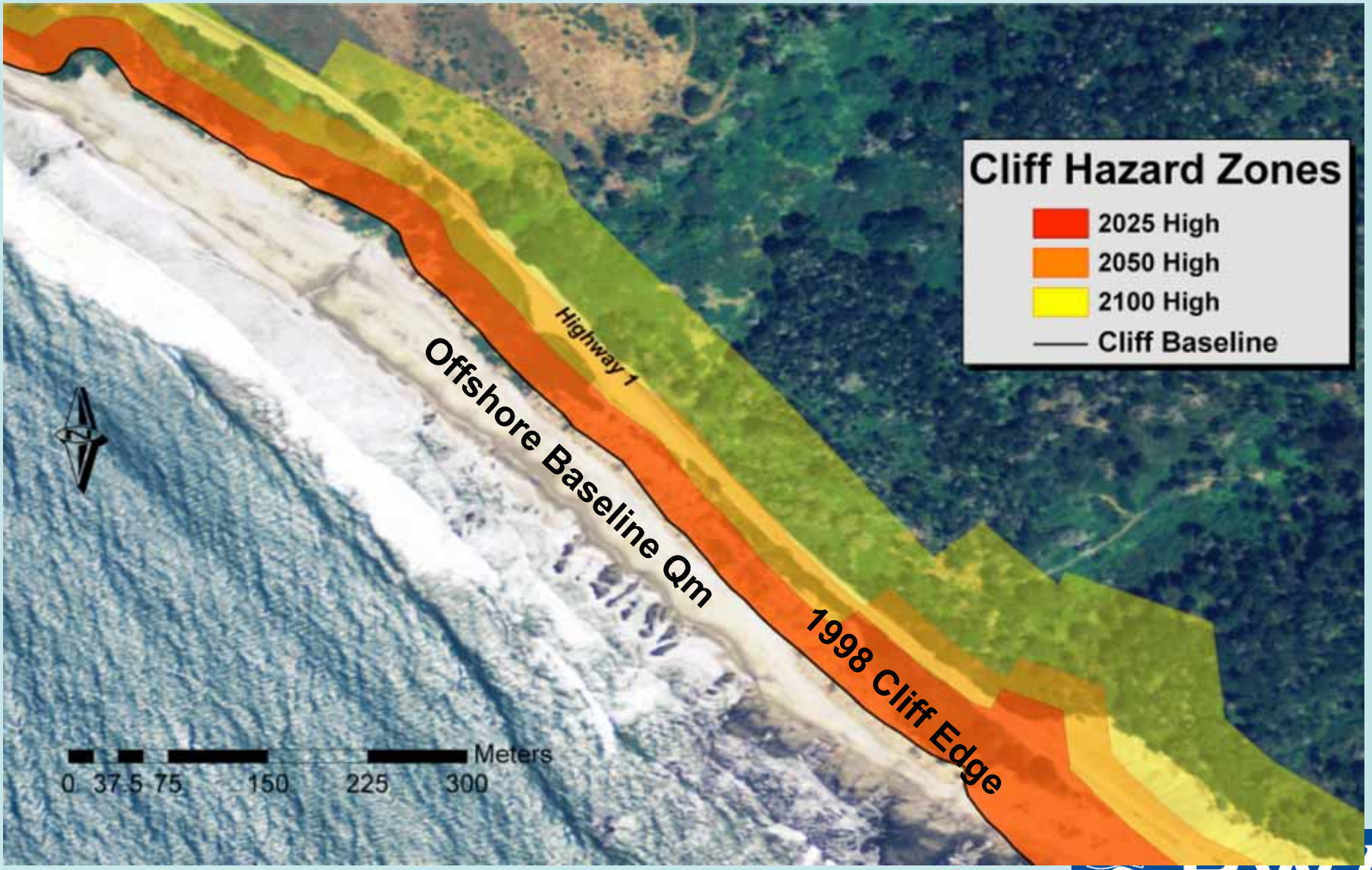
Cliff Hazard Zones



Air Photo from 2005

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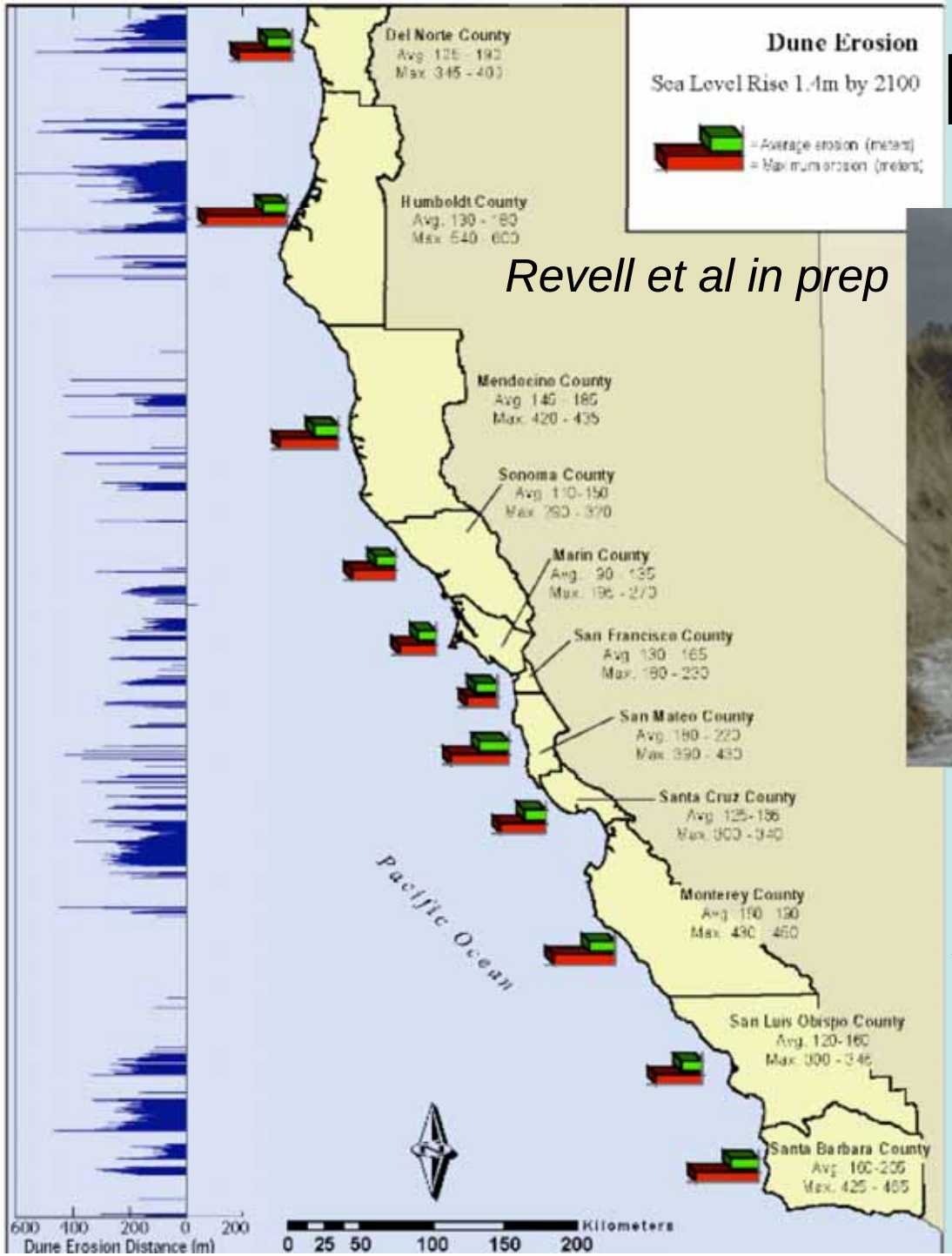
Results - Dunes



Revell et al in prep

- Majority of Norcal "accreting"
- Accreting to Erosion reversal in sign seen between 2050 and 2100
- 300 km or 185 miles

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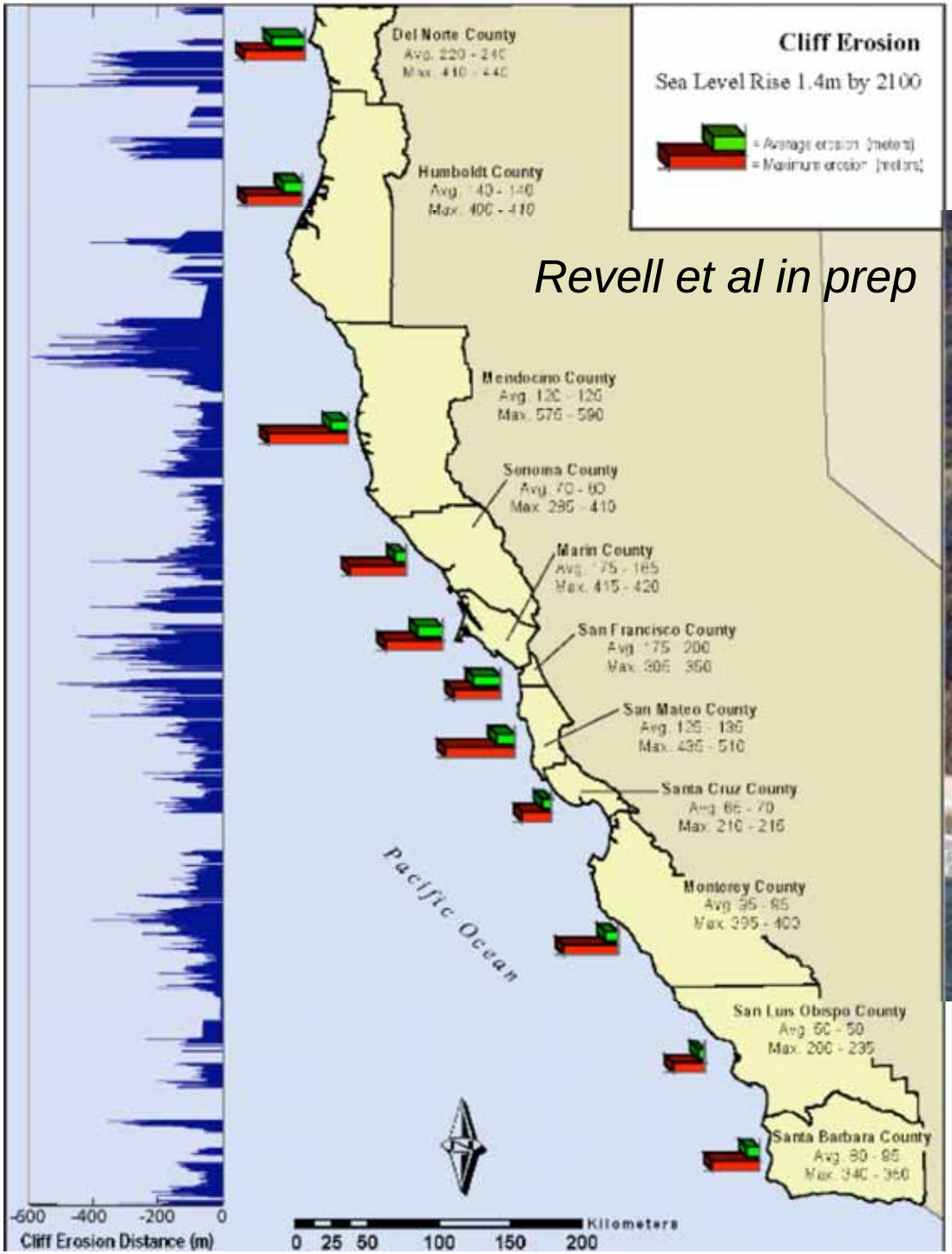
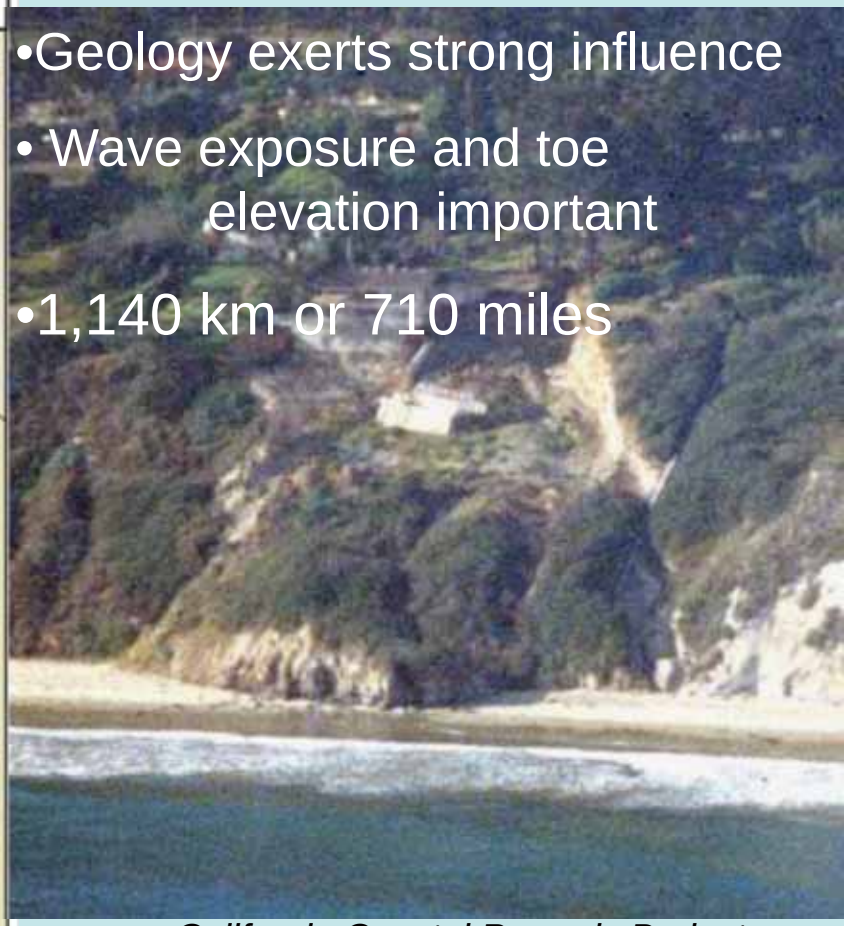
Results - Cliffs



Revell et al in prep

- Geology exerts strong influence
- Wave exposure and toe elevation important
- 1,140 km or 710 miles



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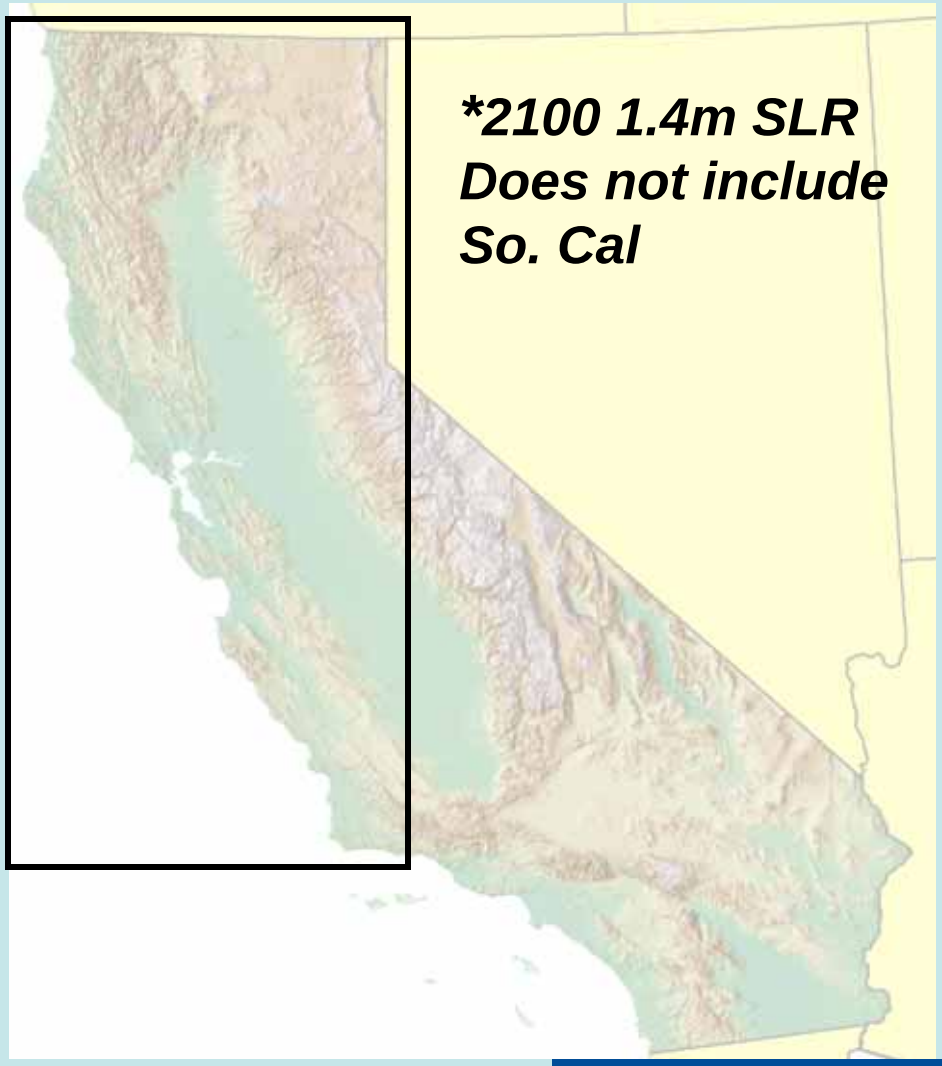
Results – Total Erosion*

County	Total erosion miles^2 (km^2)
Del Norte	4.5 (11.7)
Humboldt	6.1 (15.8)
Mendocino	8.3 (21.5)
Sonoma	2.2 (5.7)
Marin	4.7 (12.2)
San Francisco	0.5 (1.4)
San Mateo	3.2 (8.3)
Santa Cruz	1.8 (4.7)
Monterey	4.4 (11.4)
San Luis Obispo	2.9 (7.5)
Santa Barbara	2.6 (6.7)
TOTAL	41 (213.8)



***2100 1.4m SLR**
***Does not include So. Cal**

Revell et al in prep

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(:a

There is an inherent conflict between the static property boundaries and the dynamic shoreline….

We need to continue to evolve our thinking to incorporate future changes.

Coastal Armoring Tradeoffs – Fort Ord

Removal of Shoreline armoring is possible in some cases and the coast can be restored.

2002

2005

Source: California Coastal Records Project

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Surfer's Point – A Current Opportunity

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Policy and Management Recommendations # 1

1. **Integrate future sea level rise and accelerating erosion into coastal policies – CA LCP, LUP revisions, Vision**
2. **Limit scales of development in areas at risk from SLR – setbacks, size of development, uses.**
3. **Preserve adjacent uplands to keep options open.**
4. **Maintain historic ecological linkages between oceans, beaches, dunes, and wetlands – MLPA, RSM.**
5. **Cost-benefit analyses should explicitly evaluate the social, recreational and environmental tradeoffs of adaptation strategies. Multiple time horizons…**

Policy and Management Recommendations # dos

6. **Adopt policies to avoid future erosion hazards- e.g. managed retreat, rolling easements, transfer dev.**
7. **Have future seawalls bonded to have upfront costs for removal, maintenance at end of structure life/ nuisance**
8. **Review flood insurance programs in light of SLR**
9. **Conduct local vulnerability assessment of future erosion and flooding hazards**
10. **Communicate results with the planning jurisdictions and policy decisions makers…**

Long term vision…

Study Products

Photo by D. Revell – 2/23/08

Photo by P. Barnard

- Methodology for evaluating coastal erosion and SLR for different backshore types
- Down-scalable model for evaluating local impacts of climate change
- GIS erosion hazard zones of two scenarios at 3 planning horizons
- Flood elevations for the CA coast
- Estimates of future erosion rates
- Erosion rates by geologic unit

Revell et al in prep

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Future Research Needs

Photo by D. Revell – 12/07/07

- New LIDAR flight – top of bluffs, 10m contour; bathymetry
- Long term monitoring– seasonal and storm response of sand levels, slopes, toe elevations, widths
- Ensemble of GCM outputs
- Levee and coastal structure evaluation
- Ecological and physical linkages important for erosion reduction
- More detailed localized and regional studies
- Tectonic uplift/subsidence rates along the coast
- Higher resolution geology - rock hardness, failure mechanisms
- Changes to fluvial flooding from elevated sea levels

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Acknowledgements

- **Ocean Protection Council** – Chris Blackburn
- **PWA** –Justin Vandever, Brian Spear, Jeremy Lowe, Seungjin Baek, and Damien Kunz
- **Pacific Institute** – Peter Gleick, Matt Heberger, Heather Cooley
- **Expert Review** – Gary Griggs, Cheryl Hapke, Peter Ruggiero, Lesley Ewing, Adam Young, Patrick Barnard and Nicole Kinsman
- **Scripps** –Ron Flick, Peter Bromirski, Nick Graham
- **USGS** – Dan Cayan, Patrick Barnard
- **CDIP** – Bill O'Reilly, Julie Thomas
- **DCE Planning** - Brian Fulfrost
- **OST** - Amber Mace

THANK YOU!!!

For More Information

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Report

http://www.energy.ca.gov/publications/displayOneReport.php?pubNum=PWAOPC-1000-2009-013

GIS Data - Results

http://www.pacinst.org/reports/sea_level_rise/index.htm

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Erosion Method - Limitations

- Input Data Sets Accuracy
- Potential erosion **not** actual
- Single Climate Model Output
  - not an ensemble
  - no calibration of erosion rates with existing TWL data
- Single wave time series
  - no trends in wave climate
  - waves transformed to 10m
- GIS buffering algorithms
- LIDAR
  - post El Nino conditions are indicative of 2008

- Simplified geometric response
  - Equilibrium profile application
  - Assumed increase in erosion rates is linear
  - Feedback mechanisms ignored
- Shoreline Change Rates
  - Impact of 1998 Lidar uncertain
  - LT rates may not be indicative of current trends

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Sea Level Changes

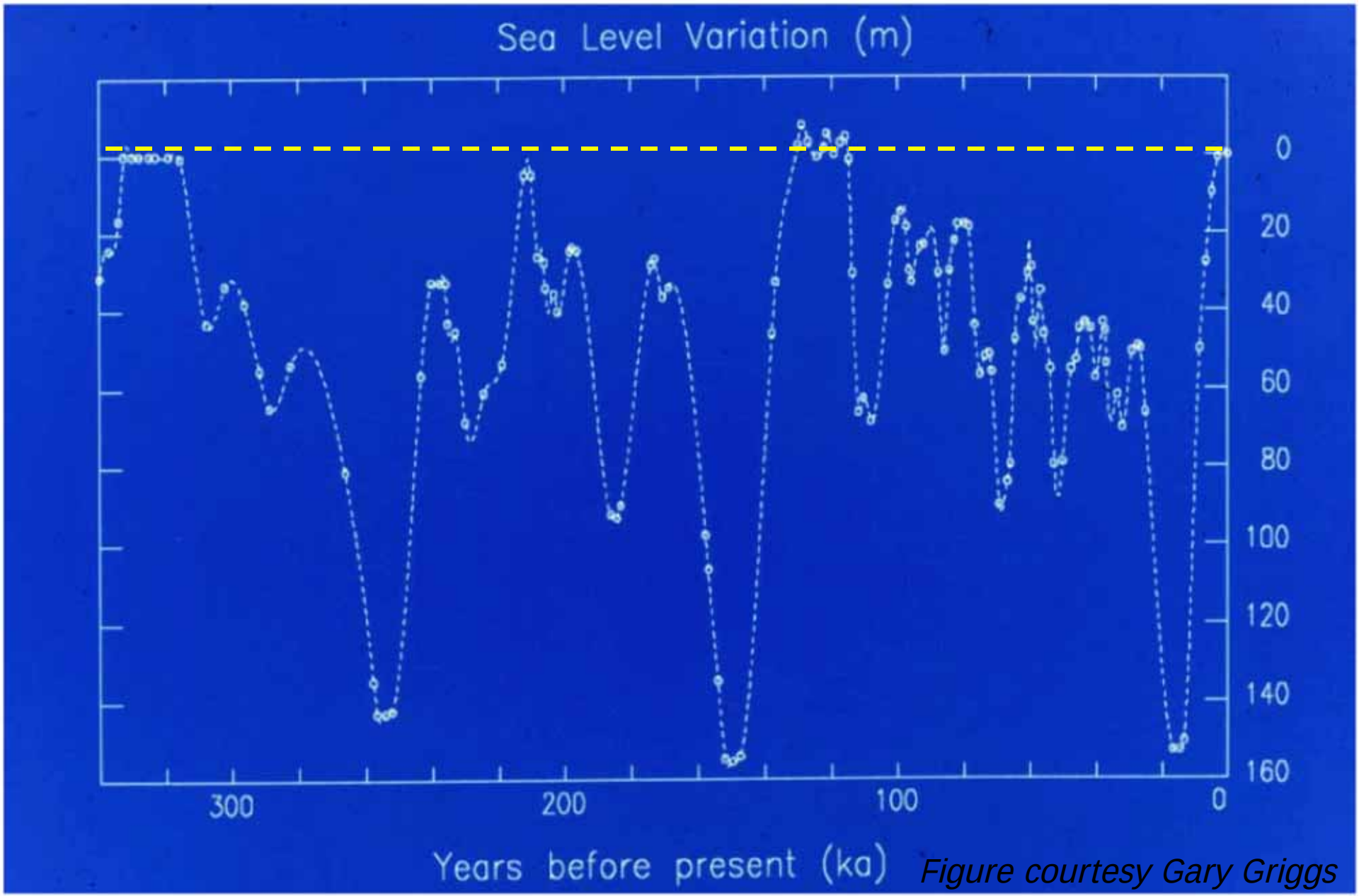
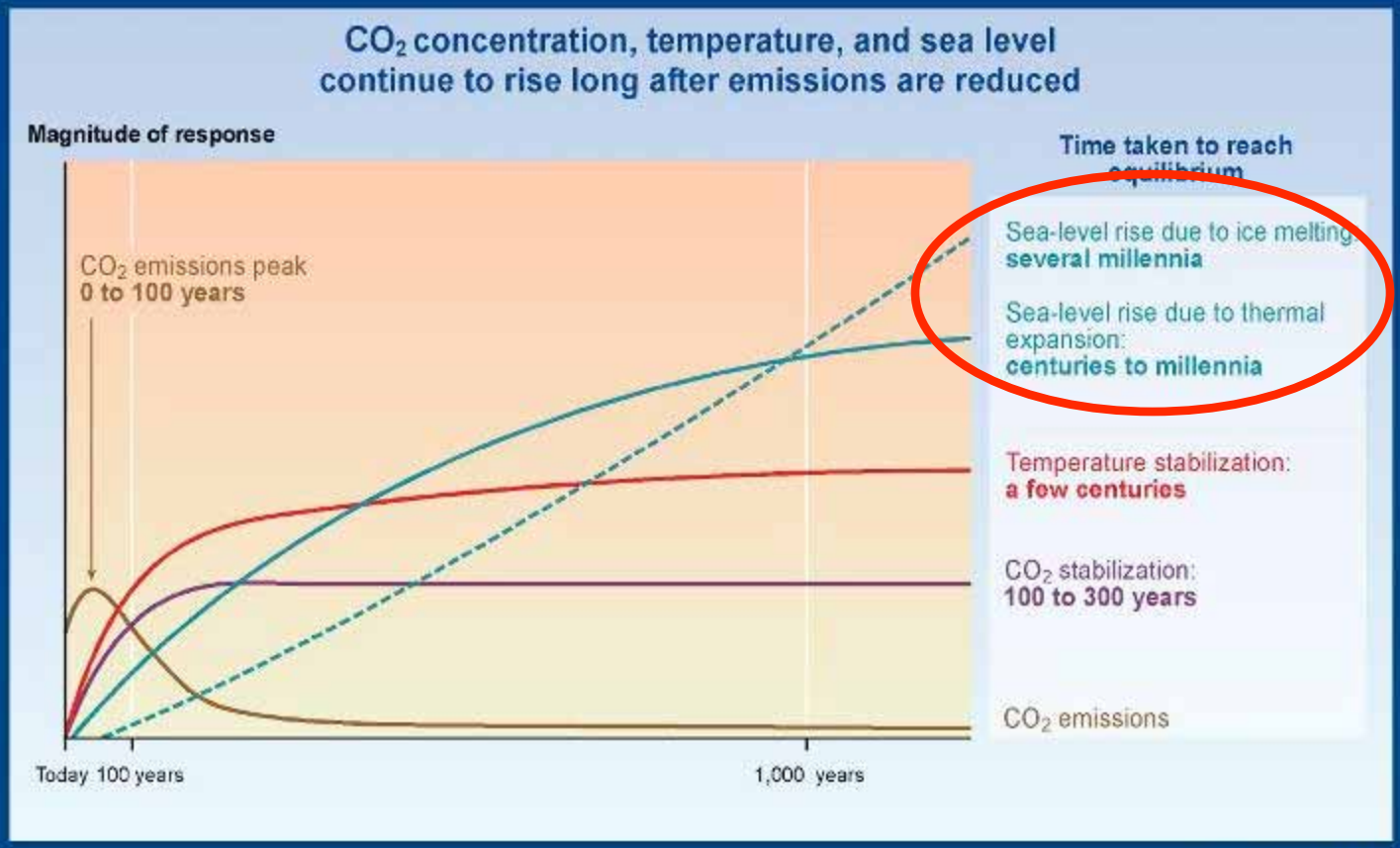


Figure courtesy Gary Griggs

Time Scales of Climate Change Impacts



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